

SIGNIFICANCE OF BIOMETRIC RATIOS AND BIOACOUSTIC ANALYSIS IN AMPHIBIAN SYSTEMATICS¹

DEBJANI ROY, AMARENDRA SARMA, BIJOYLAKSHMI BORAH AND BAKORDOR W. BANNET²

(With one text-figure and one plate)

Key words: Amphibia, systematics, morphometric measurement, biometric ratio, bioacoustic analysis

Out of the listed 4522 amphibian species of the world, 56 species are reported from the northeastern region of India. These reports are based on the morphological characters. In recent years, bioacoustic analysis of species-specific mating calls of frogs are shown to have important relevance to amphibian systematics. The question that arises now is, whether mere deviation in call pattern should be the basis for new species identification or should there also be an attempt to correlate call differences with differences in morphological characters?

The works of Kauri (1959), Berger (1966) and Tinsley (1973, 1975) gave an insight to this problem. These works showed that absolute measurements of body parts may vary but their ratios remain almost constant between individuals within the same species. Thus, when an intraspecific call variation is recorded, the biometric ratios of the individuals that differ in call pattern should also be worked out. If both the call pattern as well as the biometric ratios vary from the known records, only then should it be recorded as a new species.

The present report constitutes the first detailed account of Indian amphibians describing the call pattern in terms of temporal and spectral characters, absolute measurements and biometric ratios for 10 species from northeast India, which are of obvious utility for any future systematic work on Indian amphibians.

INTRODUCTION

With its wide range of variation in climate, geography and topography, the Indian subcontinent has a rich faunal distribution. The distribution of amphibians is very uneven across India, with the highest concentration in the northeast and the western ghats of the West Peninsular region. Because of its dense tropical forests, varying altitudinal gradients and relatively little ecological disturbance, the northeastern region shows richness and diversity of Indian amphibian species. Out of the listed

4522 amphibian species (WWF, 1994) of the world, 207 are found in India of which 56 have so far been reported from the northeastern region (BCPP CAMP Report 1997). Yet the northeastern region remains unattractive for field research, probably due to its difficult terrain. The amphibians therefore, are incompletely known and require extensive survey.

The existing faunal record of 56 amphibian species from the northeast is based on morphological characters (Pillai and Chanda 1976, Chanda 1994). Recent work from India (Roy and Elepfandt 1993, Roy 1994, Roy *et al.* 1995) and abroad (Ryan 1985, 1986; Schneider and Sinsch 1992; Sinsch and Schneider 1996) has demonstrated that anuran mating calls constitute an important character for species identification,

¹Accepted February, 1997

²Institute of Self Organising Systems and Biophysics North-Eastern Hill University, NEHU Campus, Shillong 793022, Meghalaya, India.

more distinctive than morphological characters. Roy and Elepfandt (1993) recorded three different advertisement calls from frogs, all of which were identified morphologically as *Rana limnocharis*, currently known as *Limnonectes limnocharis*. These differences suggest that the so called *R. limnocharis* in northeast India is not one species but a composition of several species of similar morphological appearance. Similar results have been reported by Sarma (1996). These results clearly suggest the necessity of re-examining *R. limnocharis* from the northeast with biometric and bioacoustic studies. It is interesting to note that in Nepal, which neighbours northeast India, the previous *R. limnocharis* (= *Limnonectes limnocharis*) has been subdivided into 4 species, namely *R. limnocharis* proper, *R. sahyadrensis*, *R. nepalensis* and *R. pierrei*, all of them belonging to one *R. limnocharis* group (Dubois 1975). Their separation has been done on the basis of the species mating call. Among recent examples are the yellow-bellied toad in northern Greece consisting of several subspecies of *Bufo variegata* (Vasara *et al.* 1991), European lake frog *Rana ridibunda* (Schneider and Sinsch 1992), the water frogs of Greece (Schneider *et al.* 1993) and pool frogs of Europe *Rana lessonae* (Sinsch and Schneider 1996).

The question now is whether mere deviation of the call pattern should be the basis for species identification or should there also be an attempt to correlate call differences with differences in morphological characters. The works of Kauri (1959), Berger (1966) and Tinsley (1973, 1975) give an insight into this problem. Tinsley (1973, 1975) showed that whereas absolute measurements of body parts may vary, their ratios remain almost constant between individuals within the same species. The ratios vary depending upon ecological interactions which may account for their adaptation and change in behavioural pattern in different ecological niches. Thus, when an intraspecific call variation is recorded, the biometric ratios of the individuals that differ in call pattern should also

be worked out. If both the call pattern and the biometric ratios vary from the known records, only then should the specimen be recorded as a new species.

With this in mind, survey was taken up during the breeding season of the amphibians for 2 consecutive years 1994 and 1995 in northeast India. This is the first detailed account, describing absolute measurements, biometric ratios and call pattern in terms of temporal and spectral characters of 10 Indian amphibian species namely — *Limnonectes limnocharis*, *Limnonectes khasiana*, *Hyla annectens*, *Polypedates maculatus*, *Euphlyctis cyanophlyctis*, *Rana alticola*, *Polypedates leucomystax*, *Amolops formosus*, *Bufo melanostictus* and *Hoplobatrachus tigerinus*.

The present work also gives detailed descriptions of colour patterns of live specimens. Early descriptions on coloration of frogs from northeast India are based on preserved specimens. As a result, sometimes the colour descriptions of preserved specimens do not match with the coloration of live specimens, e.g., *Hyla annectens* was reported to be dark grey to slate coloured (Chanda 1994) but our observation of live *Hyla annectens* shows that they are dorsally very bright green. Correct description of coloration is also of great significance in amphibian taxonomy (Nussbaum and Sheng 1995).

MATERIALS AND METHODS

Survey, call recordings and collections were carried out in Assam and Meghalaya during the breeding period from May to August in two consecutive years, 1994 and 1995. Field recordings and collections were made daily from around 1800 hrs sometimes until midnight. Large numbers were observed on days with cloud cover or moderate rainfall in comparison to dry, hot days and days with heavy rainfall.

The calls were recorded on a professional SONY WM-6DC cassette recorder with an

unidirectional AKG C451EB shotgun condenser microphone held approximately 40-60 cm away from the calling frog. The calls were stored on Maxell XLII cassette tapes. Sound pressure level was measured by playing back isolated calls on a Philips double cassette player DR920 with playback volume fixed at volume 3 and the CYGNET 2021 sound pressure level held approximately 1 m away from the sound source.

Recorded acoustic stimuli were digitized via a Microsoft analogue to digital interface board onto an IBM PC and stored on diskettes. Oscillograms shown as waveform display of amplitude versus time trace; sonogram as the frequency versus time trace with amplitude represented by shades of grey and mean spectra showing the maximum energy concentration at a particular frequency band were prepared with a computerised Fast Fourier Transformation (FFT) system after passing through band pass filters.

Measurements of the following 15 absolute morphometric characters were recorded from at least 5 or more individuals each of males and females separately from each of the 10 species studied, except for *Limnonectes khasiana*, where only 3 males were found and no females were found. From the morphometric measurements 8 biometric ratios were worked out. All measurements were accurate to 0.1 mm.

A. MORPHOMETRIC CHARACTERS

1. Body length: Snout to vent length (SVL)
2. Body width: Measured at the widest part across the abdomen
3. Head width (min.): At the tip of the snout parallel to the nostril
4. Head width (max): Measured at the widest part across the eyes
5. Snout length: Perpendicular distance from below the nostril to the tip of the mouth

6. Eye diameter: Transverse distance across the exposed orbits.
7. Interocular distance: Transverse distance between inner bases of the circum-orbital plaques
8. Nostril diameter: Measured across the long axis of the nostril
9. Internarial distance: Distance between inner margin of the nostril bordering flaps
10. Hindlimb length: Vent to tip of the 5th toe
11. Tibia length: Medial measurement of the outer ventral surface of the digit
12. 4th toe length: Measurement of the outer ventral surface of the digit
13. Total forelimb length: Origin of the limb to the tip of the 1st finger
14. Lower forelimb length: Outer angle of the elbow to the tip of the 1st finger
15. 1st finger length: Base to the tip of the 1st finger

B. BIOMETRIC RATIOS

1. Head width (Min) / Head width (Max)
2. Snout length / Head width (Min)
3. Eye diameter / Interocular distance
4. Nostril diameter / Internarial distance
5. Tibia length / 4th toe length
6. 1st finger length / Lower forelimb length
7. Total forelimb length / Body length
8. Body length / Hindlimb length

C. CALL CHARACTERS

1. Call duration (sec): Duration from the beginning of a call to its end

TABLE 1
ABSOLUTE MEASUREMENTS (IN CMS) OF 15 MORPHOMETRIC CHARACTERS OF *LIMNONECTES LIMNOCHARIS*, *LIMNONECTES KHASIANA*, *HYLA ANNECTENS*, *POLYPEDATES MACULATUS*, *EUPHLYCTIS CYANOPHLYCTIS*, *RANA ALTICOLA*, *POLYPEDATES LEUCOMYSTAX*, *AMOLOPS FORMOSUS*, *BUFO MELANOSTICTUS*, *HOPLOBATRACHUS TIGERINUS*

Characters	<i>L. limnocharis</i>		<i>L. khasiana</i>		<i>H. annectens</i>		<i>P. maculatus</i>		<i>E. cyanophlyctis</i>	
	Male	Female	Male	Male	Female	Male	Female	Male	Female	
Body length	4.11 ± 0.36	4.75 ± 0.36	3.50 ± 0.05	3.82 ± 0.17	4.83 ± 0.23	4.14 ± 0.17	4.56 ± 0.27	3.90 ± 0.32	3.40 ± 0.66	
Body width	2.11 ± 0.37	2.50 ± 0.21	2.40 ± 0.10	1.37 ± 0.04	1.93 ± 0.18	1.80 ± 0.08	1.80 ± 0.10	1.60 ± 0.04	1.40 ± 0.32	
Head width (Min)	0.96 ± 0.10	1.12 ± 0.04	0.65 ± 0.05	0.67 ± 0.04	0.80 ± 0.14	0.96 ± 0.08	1.02 ± 0.04	0.90 ± 0.18	0.70 ± 0.18	
Head width (Max)	1.50 ± 0.13	1.70 ± 0.07	1.80 ± 0.10	1.12 ± 0.08	1.50 ± 0.00	1.50 ± 0.06	1.58 ± 0.11	1.30 ± 0.00	1.10 ± 0.19	
Snout length	0.70 ± 0.08	0.75 ± 0.05	0.45 ± 0.50	0.52 ± 0.08	0.70 ± 0.00	0.68 ± 0.04	0.76 ± 0.08	0.63 ± 0.04	0.58 ± 0.09	
Eye diam.	0.48 ± 0.05	0.50 ± 0.07	0.45 ± 0.50	0.47 ± 0.12	0.56 ± 0.04	0.56 ± 0.04	0.61 ± 0.04	0.53 ± 0.04	0.47 ± 0.08	

2. Call period (sec): Duration from the beginning of a call to the beginning of the next call
3. Pulse number: The number of individual components of each call (FFT length - 256; Overlap- 50%; Window - Hamming)
4. Dominant frequency (kHz): The frequency with maximum intensity
5. Frequency domain (kHz): The range of frequencies that differ by less than 10dB intensity from the dominant frequency.

After noting down the morphometric measurements and recording the calls, a few specimens from each species were preserved in 8% formaldehyde for photography and drawing and the rest were released in their natural habitat.

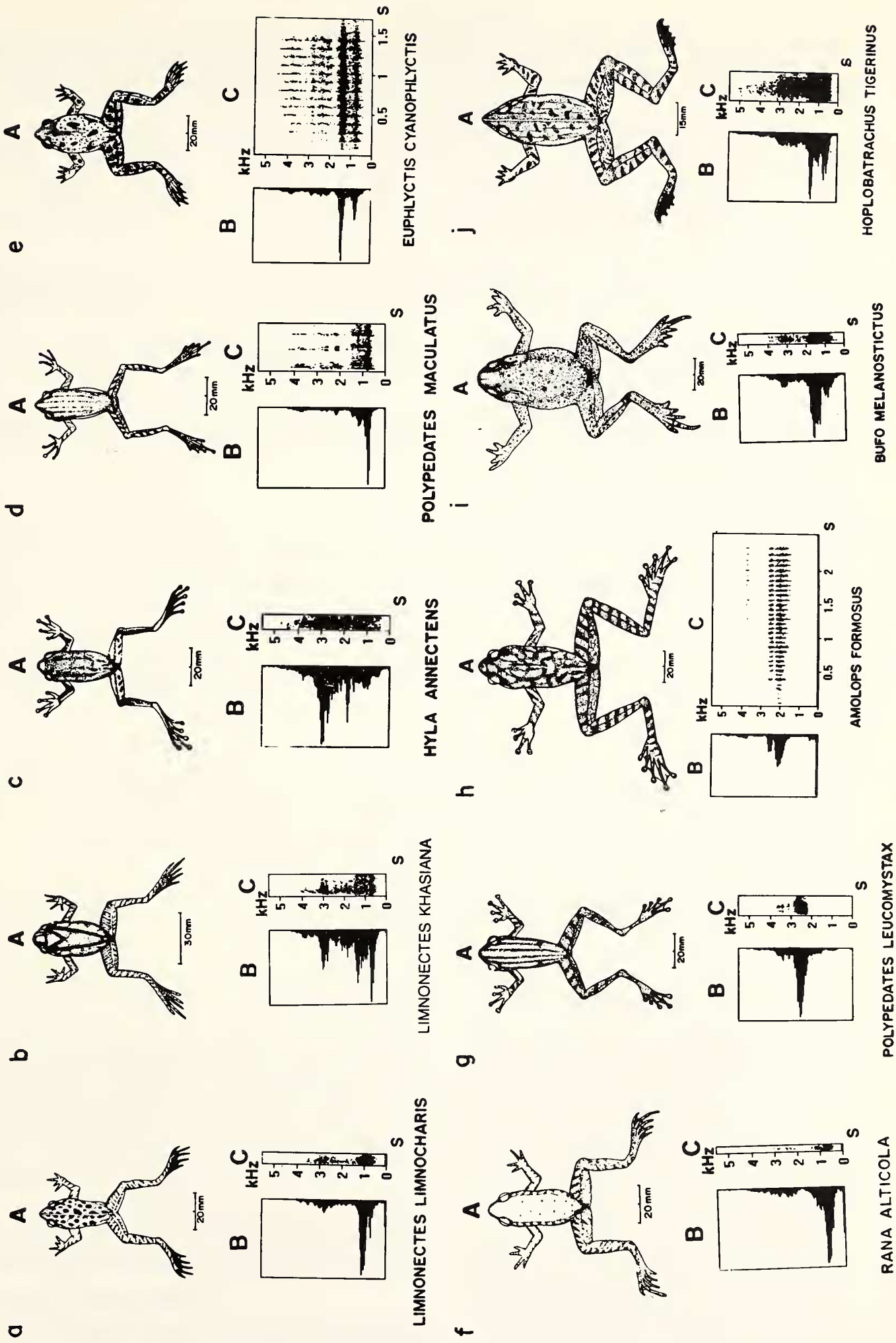
OBSERVATIONS

15 absolute measurements (Table 1); 8 biometric ratios (Table 2) and temporal and spectral data after acoustic analysis of the mating calls (Table 3) of 10 anuran species from northeast India have been compiled. In Plate 1 'A' represents the line drawings for the different frog species (to scale); 'B' shows the mean spectra of the mating calls and 'C' the corresponding sonogram (FFT length: 265; Overlap: 50%, Window: Hamming). Fig. 2 shows the waveform representation or oscillogram of a single call for each of these 10 species.

Limnonectes limnocharis (Plate 1a. A, B, C & Fig. 1a; Tables 1, 2 & 3)

1. **Habit and Habitat:** Known as the cricket frog, it is generally found in shallow marshes, damp grassland near canals and ditches and in flooded fields during the rainy season. Before and during the breeding period they hide

Debjani et al.: *Amphibian systematics*



A: Line drawings of different species to scale; B: Mean spectrum of mating call of the corresponding species;
 C: Corresponding sonogram (FFT length - 256, Overlap 50% Window - Hamming)

TABLE 1 (contd)

ABSOLUTE MEASUREMENTS OF 15 MORPHOMETRIC CHARACTERS OF *LIMNONECTES LIMNOCHARIS*, *LIMNONECTES KHASIANA*, *HYLA ANNECTENS*, *POLYPEDATES MACULATUS*, *EUPHLYCTIS CYANOPHLYCTIS*, *RANA ALTICOLA*, *POLYPEDATES LEUCOMYSTAX*, *AMOLOPS FORMOSUS*, *BUFO MELANOSTICTUS*, *HOPLOBATRACHUS TIGERINUS*

Characters	<i>L. limnocharis</i>		<i>L. khasiana</i>		<i>H. annectens</i>		<i>P. maculatus</i>		<i>E. cyanophlyctis</i>	
	Male	Female	Male	Male	Female	Male	Female	Male	Female	
Interocular distance	0.33 ± 0.11	0.40 ± 0.07	0.35 ± 0.50	0.50 ± 0.00	0.73 ± 0.04	0.52 ± 0.07	0.55 ± 0.07	0.43 ± 0.04	0.35 ± 0.07	
Nostril diam.	0.20 ± 0.00	0.20 ± 0.00	0.10 ± 0.00	0.17 ± 0.04	0.20 ± 0.00	0.12 ± 0.04	0.10 ± 0.00	0.23 ± 0.04	0.22 ± 0.04	
Internarial distance	0.46 ± 0.04	0.40 ± 0.04	0.70 ± 0.00	0.30 ± 0.00	0.40 ± 0.00	0.30 ± 0.00	0.36 ± 0.08	0.33 ± 0.04	0.32 ± 0.04	
Hind limb length	6.48 ± 0.57	7.62 ± 0.45	5.30 ± 0.10	5.70 ± 0.12	7.83 ± 0.47	6.52 ± 0.21	7.12 ± 0.69	5.80 ± 0.28	5.10 ± 0.81	
Tibia length	1.75 ± 0.21	2.17 ± 0.12	2.40 ± 0.10	1.70 ± 0.12	2.20 ± 0.16	2.12 ± 0.16	2.34 ± 0.24	1.70 ± 0.04	1.50 ± 0.21	
Fourth toe length	1.82 ± 0.10	2.37 ± 0.23	1.20 ± 0.10	1.70 ± 0.12	2.30 ± 0.14	1.92 ± 0.07	1.98 ± 0.21	1.90 ± 0.09	1.70 ± 0.35	
Total fore limb length	1.51 ± 0.30	2.12 ± 0.12	2.10 ± 0.10	2.72 ± 0.08	3.40 ± 0.14	2.80 ± 0.10	2.92 ± 0.27	1.80 ± 0.04	1.60 ± 0.28	
Lower fore limb length	1.33 ± 0.21	1.42 ± 0.14	1.30 ± 0.10	2.03 ± 0.16	2.53 ± 0.23	2.02 ± 0.29	2.16 ± 0.28	1.40 ± 0.00	1.00 ± 0.27	
First finger length	0.61 ± 0.09	0.70 ± 0.07	0.45 ± 0.05	0.45 ± 0.05	0.53 ± 0.04	0.66 ± 0.04	1.90 ± 0.24	1.76 ± 0.09	0.60 ± 0.15	

themselves among vegetation and under stones. They are good jumpers, when disturbed escape into dense vegetation and water. They do not remain in deep water for long but swim back immediately to the bank.

2. **Coloration** (Plate 1a.A): Dorsal surface grey with black spots; a wide whitish median line; ventral surface white or creamish; throat grey, sometimes black granulate.

3. **Morphometric measurements and biometric ratios** (Tables 1 & 2): Absolute

measurements of 15 morphometric characters and 8 biometric ratios were recorded from 10 males and 10 females respectively.

4. **Call characteristics** (Plate 1a. BC & Fig. 1a; Table 3): The calls are given in rapid succession. Each call lasts about 0.11 seconds with 56 pulses, given at intervals of approximately 0.252 seconds. The call has a single dominant frequency at about 1.08 kHz, extending from 0.35 kHz to 4.40 kHz. The sound pressure level (SPL) of the call is 68.1dB.

TABLE 1 (contd.)

ABSOLUTE MEASUREMENTS (IN CMS) OF 15 MORPHOMETRIC CHARACTERS OF *LIMNONECTES LIMNOCHARIS*, *LIMNONECTES KHASIANA*, *HYLA ANNECTENS*, *POLYPEDATES MACULATUS*, *EUPHLYCTIS CYANOPHLYCTIS*, *RANA ALTICOLA*, *POLYPEDATES LEUCOMYSTAX*, *AMOLOPS FORMOSUS*, *BUFO MELANOSTICTUS*, *HOPLOBATRACHUS TIGERINUS*

Characters	<i>R. alticola</i>		<i>P. leucomystax</i>		<i>A. formosus</i>		<i>B. melanostictus</i>	<i>H. tigerinus</i>
	Male	Female	Male	Female	Male	Female	Male	Male
Body length	5.10 ± 0.08	5.45 ± 0.05	5.40 ± 0.18	8.40 ± 0.26	4.43 ± 0.13	8.20 ± 1.03	7.80 ± 0.20	14.33 ± 4.18
Body width	1.33 ± 0.12	1.65 ± 0.05	1.60 ± 0.22	2.63 ± 0.16	2.20 ± 0.08	3.58 ± 0.36	3.90 ± 0.08	5.16 ± 0.84
Head width (Min)	0.96 ± 0.09	1.15 ± 0.05	1.20 ± 0.11	1.80 ± 0.04	1.20 ± 0.08	1.82 ± 0.09	1.60 ± 0.12	3.60 ± 0.14
Head width (Max)	1.46 ± 0.16	1.75 ± 0.05	1.90 ± 0.09	2.70 ± 0.04	1.80 ± 0.08	2.60 ± 0.42	2.90 ± 0.08	4.40 ± 0.29
Snout length	0.86 ± 0.09	0.08 ± 0.00	0.97 ± 0.08	1.30 ± 0.04	0.86 ± 0.04	1.18 ± 0.16	1.10 ± 0.05	1.90 ± 0.12
Eye diameter	0.66 ± 0.04	0.65 ± 0.05	0.68 ± 0.03	0.80 ± 0.00	0.86 ± 0.04	0.81 ± 0.39	0.10 ± 0.005	1.70 ± 0.08
Interocular distance	0.50 ± 0.00	0.45 ± 0.05	0.78 ± 0.11	1.10 ± 0.00	0.46 ± 0.04	0.76 ± 0.12	0.65 ± 0.05	1.10 ± 0.04
Nostril diameter	0.20 ± 0.00	0.20 ± 0.00	0.10 ± 0.00	0.16 ± 0.02	0.20 ± 0.00	0.22 ± 0.04	0.30 ± 0.00	0.23 ± 0.04
Internarial distance	0.50 ± 0.08	0.55 ± 0.05	0.41 ± 0.03	0.70 ± 0.00	0.56 ± 0.04	0.83 ± 0.21	0.50 ± 0.00	0.63 ± 0.04
Hind limb length	7.30 ± 0.07	7.60 ± 0.10	8.35 ± 0.16	11.90 ± 0.32	8.66 ± 0.13	13.74 ± 1.33	9.90 ± 0.30	20.70 ± 2.56
Tibia length	2.20 ± 0.08	2.45 ± 0.05	2.77 ± 0.26	3.76 ± 0.20	3.04 ± 0.04	4.66 ± 0.22	2.60 ± 0.12	5.40 ± 0.28
Fourth toe length	2.06 ± 0.09	2.25 ± 0.05	2.28 ± 0.21	2.93 ± 0.30	2.32 ± 0.09	3.74 ± 0.17	2.70 ± 0.12	5.30 ± 0.49
Total fore limb length	2.90 ± 0.21	2.65 ± 0.05	3.45 ± 0.04	5.23 ± 0.20	3.16 ± 0.04	4.84 ± 0.67	5.00 ± 0.05	6.60 ± 0.41
Lower fore limb length	1.76 ± 0.16	1.65 ± 0.05	2.40 ± 0.15	3.80 ± 0.14	2.32 ± 0.09	3.70 ± 0.20	3.00 ± 0.05	4.50 ± 0.20
First finger length	0.65 ± 0.05	0.75 ± 0.05	0.68 ± 0.06	1.16 ± 0.24	0.86 ± 0.04	1.36 ± 0.17	0.65 ± 0.05	1.20 ± 0.08

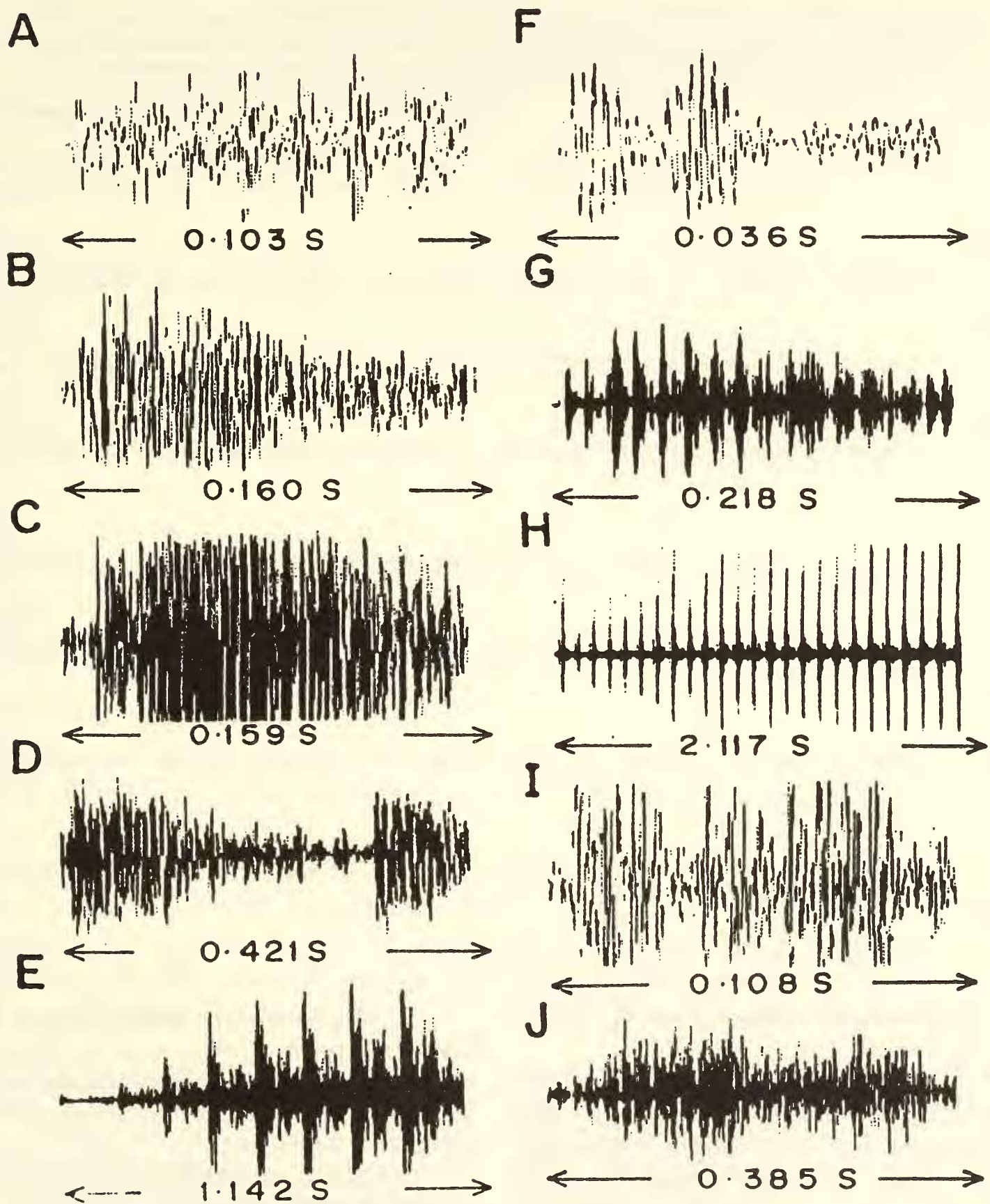


Fig. 1. Oscillograms shown as waveform display of amplitude versus time trace for a single mating call of -
 a. *Limnonectes limnocharis*; b. *Limnonectes khasiana*; c. *Hyla annectens*; d. *Polypedates maculatus*;
 e. *Euphlyctis cyanophlyctis*; f. *Rana alticola*; g. *Polypedates leucomystax*; h. *Amolops formosus*;
 i. *Bufo melanostictus*; j. *Hoplobatrachus tigerinus*.
 (FFT length - 256; Overlap - 50%; Windows - Hamming)

TABLE 2

BIOMETRIC RATIOS OF *LIMNONECTES LIMNOCHARIS*, *LIMNONECTES KHASIANA*, *HYLA ANNECTENS*, *POLYPEDATES MACULATUS*, *EUPHLYCTIS CYANOPHLYCTIS*, *RANA ALTICOLA*, *POLYPEDATES LEUCOMYSTAX*, *AMOLOPS FORMOSUS*, *BUFO MELANOSTICTUS*, *HOPLOBATRACHUS TIGERINUS*

Characters	<i>L. limnocharis</i>		<i>L. khasiana</i>		<i>H. annectens</i>		<i>P. maculatus</i>		<i>E. cyanophlyctis</i>	
	Male (10)	Female (10)	Male (3)	Male (7)	Female (5)	Male (10)	Female (6)	Male (10)	Female (10)	
Head width (Min) /Head width (Max)	0.63 ± 0.04	0.65 ± 0.05	0.35 ± 0.05	0.59 ± 0.02	0.46 ± 0.00	0.63 ± 0.06	0.64 ± 0.02	0.58 ± 0.07	0.71 ± 0.14	
Snout length /Head width (Min)	0.73 ± 0.11	0.66 ± 0.06	0.68 ± 0.02	0.79 ± 0.08	1.03 ± 0.03	0.70 ± 0.05	0.74 ± 0.05	0.86 ± 0.12	0.69 ± 0.08	
Eye diameter /Inter ocular distance	1.30 ± 0.08	1.25 ± 0.04	1.29 ± 0.04	0.85 ± 0.21	0.85 ± 0.00	0.91 ± 0.43	1.11 ± 0.07	1.32 ± 0.08	1.23 ± 0.02	
Nostril diameter /Inter narial distance	0.43 ± 0.04	0.42 ± 0.04	0.14 ± 0.00	0.57 ± 0.14	0.50 ± 0.00	0.39 ± 0.13	0.28 ± 0.05	0.68 ± 0.04	0.69 ± 0.04	
Tibia length /Fourth toe length	0.96 ± 0.13	0.99 ± 0.09	2.00 ± 0.08	0.95 ± 0.02	0.91 ± 0.00	1.10 ± 0.05	1.17 ± 0.03	0.91 ± 0.10	0.87 ± 0.01	
First finger length /Lower fore limb length	0.47 ± 0.04	0.49 ± 0.03	0.34 ± 0.01	0.21 ± 0.01	5.40 ± 0.00	0.32 ± 0.03	0.32 ± 0.02	0.59 ± 0.08	0.54 ± 0.06	
Total fore limb length /Body length	0.41 ± 0.03	0.44 ± 0.02	0.59 ± 0.02	0.71 ± 0.02	0.70 ± 0.00	0.67 ± 0.02	0.63 ± 0.03	0.46 ± 0.03	0.46 ± 0.02	
Body length /Hind limb length	0.63 ± 0.03	0.61 ± 0.03	0.66 ± 0.005	0.66 ± 0.02	0.66 ± 0.00	0.62 ± 0.01	0.63 ± 0.03	0.66 ± 0.03	0.67 ± 0.01	

Limnonectes khasiana (Plate 1b, ABC & Fig. 1b; Tables 1, 2 & 3)

1. **Habit and Habitat:** This species is not found commonly. During our study only 3 adult calling males were collected. No females were found. Chanda (1994) reported that although this species has been recorded from Meghalaya (Bowerger 1882), he did not come across even a single specimen during his study.

2. **Coloration** (Plate 1b. A): Tiny reddish brown species. Dorsal side with brownish triangular dark patches; ventral surface light brown with dark patches.

3. **Morphometric measurements and biometric ratios** (Tables 1 & 2): Absolute measurements of 15 morphometric characters and 8 biometric ratios were recorded from 3 males. No females were found.

4. **Call characteristics** (Plate 1b.BC & Fig. 1b; Table 3): The calls are loud and given in rapid succession. Each call lasts about 0.151 s with many pulses, given at approximately 0.219 s. It is a harmonic call having dominant frequencies at about 0.67 kHz, 1.34 kHz and 3.01 kHz. The frequency domain lies in the range of 0.35 kHz to 4.20 kHz, the SPL of the call being 53.29 dB.

TABLE 2 (contd.)

BIOMETRIC RATIOS OF *LIMNONECTES LIMNOCHARIS*, *LIMNONECTES KHASIANA*, *HYLA ANNECTENS*,
POLYPEDATES MACULATUS, *EUPHLYCTIS CYANOPHLYCTIS*, *RANA ALTICOLA*, *POLYPEDATES*
LEUCOMYSTAX, *AMOLOPS FORMOSUS*, *BUFO MELANOSTICTUS*, *HOPLOBATRACHUS TIGERINUS*

Characters	<i>Rana alticola</i>		<i>Polypedates leucomystax</i>		<i>Amolops formosus</i>		<i>B. melanostictus</i>	<i>H. tigerinus</i>
	Male (7)	Female (6)	Male (10)	Female (10)	Male (10)	Female (10)	Male (10)	Male (10)
Head width (Min) /Head width (Max)	0.67 ± 0.02	0.65 ± 0.01	0.66 ± 0.03	0.66 ± 0.004	0.66 ± 0.01	0.70 ± 0.07	0.57 ± 0.03	0.81 ± 0.04
Snout length /Head width (Min)	0.88 ± 9.42	0.58 ± 0.08	0.76 ± 0.05	0.71 ± 0.02	0.71 ± 0.02	0.64 ± 0.05	0.68 ± 0.02	0.54 ± 0.02
Eye diameter /Inter ocular distance	1.33 ± 0.09	1.47 ± 0.27	0.89 ± 0.15	0.72 ± 0.00	1.88 ± 0.09	1.28 ± 0.008	1.61 ± 0.04	1.49 ± 0.03
Nostril diameter /Inter narial distance	0.41 ± 0.06	0.36 ± 0.03	0.24 ± 0.01	0.23 ± 0.03	0.35 ± 0.03	0.27 ± 0.03	0.51 ± 0.09	0.36 ± 0.04
Tibia length /Fourth toe length	1.06 ± 0.02	1.08 ± 0.005	1.19 ± 0.12	1.30 ± 0.21	1.31 ± 0.04	1.24 ± 0.02	0.96 ± 0.00	1.02 ± 0.04
First finger Length /Lower fore limb length	0.39 ± 0.05	0.45 ± 0.02	0.28 ± 0.02	0.30 ± 0.05	0.36 ± 0.004	0.36 ± 0.02	0.21 ± 0.01	0.26 ± 0.01
Total fore limb length/Body length	0.56 ± 0.05	0.48 ± 0.005	0.63 ± 0.02	0.61 ± 0.01	0.72 ± 0.01	0.58 ± 0.04	0.64 ± 0.01	0.49 ± 0.10
Body length /Hind limb length	0.69 ± 0.01	0.71 ± 0.005	0.64 ± 0.02	0.70 ± 9.42	0.49 ± 0.009	0.59 ± 0.02	0.78 ± 0.06	0.67 ± 0.11

Hyla annectens (Plate 1c.ABC & Fig. 1c; Tables 1, 2 & 3)

1. **Habit and Habitat:** Commonly known as the garden frog, mainly found in potato fields and in gardens, climbing from one tree to another. Out of the 260 valid species of this genus from the world, it is the only species found in northeast India.

2. **Coloration** (Plate 1c.A): Dorsal surface dark green with a light brown streak from eyes to nostrils; a black lateral streak present upto

groin, often terminating in black spots of different sizes with interconnections; ventral surface of the thigh yellowish; a few black spots arranged more or less in line on the ventral surface of the femur and tibia.

3. **Morphometric measurements and biometric ratios** (Tables 1 & 2): Absolute measurements of 15 morphometric characters and 8 biometric ratios were recorded from 7 males and 5 females.

4. **Call characteristics** (Plate 1c.BC & Fig.

Species	C.D.	C.P.	P.N.	L.F.	H.F.	D.F.	SPL
<i>L. limnocharis</i>	x 0.110 n 0.008	x 0.252 n 0.030	x 56 n 4.2	x 0.35 x 0.06	x 4.40 x 0.30	x 1.08 x 0.06	x 68.10 x 3.17
<i>L. khasiana</i>	x 0.151 n 0.001	x 0.219 x 0.020	x many n —	x 0.35 n 0.04	x 4.20 n 0.02	x 0.67 n 0.03 x 1.34 n 0.01 x 3.01 n 0.02	x 53.29 n 1.52
<i>H. annectens</i>	x 0.166 n 0.006	x 0.321 n 0.070	x many n —	x 0.37 n 0.02	x 4.80 n 0.10	x 1.81 n 0 x 2.78 n 0.09	x 57.48 n 0.52
<i>P. maculatus</i>	x 0.389 n 0.050	x 2.427 n 0.390	x 105 n 22.22	x 0.36 n 0.02	x 4.06 n 0.13	x 0.73 n 0	x 58.29 n 1.71
<i>E. cyanophlyctis</i>	x 1.122 n 0.370	x 3.574 n 0.490	x 9 n 4.44	x 0.33 n 0.03	x 4.36 n 0.23	x 0.78 n 0 n 1.42 n 0	x 62.03 n 1.71
<i>R. alticola</i>	x 0.020 n. 0.004	x 0.079 n 0.004	x 14 n 3.37	n 0.30 n 0.10	x 1.57 n 0.05	x 0.73 n 0.01	x 45.47 n 0.61
<i>P. leucomystax</i>	x 0.182 n 0.030	x 10.369 n 1.550	x 13 n 2.23	x 1.44 n 0.02	x 3.82 n 0.13	x 2.50 n 0.18	x 50.46 n 4.78
<i>A. formosus</i>	x 1.840 n 0.520	x 8.802 n 0.420	x 21 n 9	x 1.42 x 0.05	x 2.71 n 0.06	x 2.07 n 0 x 2.45 n 0	x 52.70 n 1.62
<i>B. melanostictus</i>	x 0.103 n 0.010	x 0.134 n 0.010	x 105 n 19.18	x 0.34 n 0.04	x 4.01 n 0.13	x 1.69 n 0.01	x 59.21 n 1.34
<i>H. tigerinus</i>	x 0.290 n 0.080	x 1.011 n 0.290	x 16 x 1.0	x 0.30 n 0.02	x 4.32 n 0.14	x 0.52 n 0.02 x 1.65 n 0.03	x 61.09 n 0.65

C.D. = Call duration in seconds; C.P. = Call period in seconds; P.N. = Pulse number; L.F. = Lower frequency in kilohertz; H.F. = Higher frequency in kilohertz; D.F. = Dominant frequency in kilohertz; SPL = Sound pressure level in decibels; x = Mean; n = Standard deviation.

The number of calls for each species is 20. Calls are of the male frogs.

1c; Table 3): The calls are loud and noisy. Each call lasts for about 0.166s with many pulses, given at intervals of 0.321 s. The call is harmonic having dominant frequencies at about 1.81 kHz and 2.78 kHz. The frequency domain extends from about 0.37 kHz to 4.80 kHz, the SPL of the call being 57.48 dB.

Polypedates maculatus (Plate 1d.ABC & Fig. 1d; Tables 1, 2 & 3)

1. **Habit and Habitat:** Found in paddy fields and marshy grasslands, also among potato and bean plantation. The calling males conceal themselves under potato leaves or other vegetation.

2. **Coloration** (Plate 1d.A): Dorsally yellowish brown to dark brown, limbs with brown and white cross bars of irregular patterns; thighs and throat light brown to yellowish; the chin and throat bear large dark oval spots.

3. **Morphometric measurements and biometric ratios** (Tables 1 & 2): Absolute measurements of 15 morphometric characters and 8 biometric ratios were recorded from 10 males and 6 females.

4. **Call characteristics** (Plate 1d. BC & Fig. 1d; Table 3): The calls are loud and distinct. At the initiation of the call, the calls have two distinct components. With the passage of time the components go on increasing in number. Each call lasts for about 0.389s, having as many as 105 pulses, given at intervals of 2.427 s. The call has a single dominant frequency at about 0.73 kHz, the frequency domain extending from about 0.36 kHz to 4.06 kHz. the SPL of the call being 58.29 dB.

Euphlyctis cyanophlyctis (Plate 1e. ABC & Fig. 1e; Tables 1, 2 & 3)

1. **Habit and Habitat:** These frogs are aquatic, found in pools, muddy swamps and canals and remain in water for long without coming onto the land. They spend most of their time floating motionless, with eyes and tip of the snout above water. When alarmed they skitter across the water surface for several feet before diving to the bottom to hide.

2. **Coloration** (Plate 1e. A): Dorsal surface light olive green or brown to almost black with irregularly arranged sooty spots; posterior surface of thigh dark, often with one or two yellow or white, irregular, longitudinal stripes; ventral surface white or with dark speckling; vocal sacs dusky.

3. **Morphometric measurements and biometric ratios** (Tables 1 & 2): Absolute measurements of 15 morphometric characters and 8 biometric ratios have been compiled for 10 males and 10 females.

4. **Call characteristics** (Plate 1e. BC & Fig. 1e; Table 3): The calls have distinct pulse components, which increase with the passage of time. Each call lasts for about 1.122 s, having about 9 pulses, given at call intervals of about 3.574 s. The call is harmonic, having dominant frequencies at about 0.78 kHz and 1.42 kHz. The frequency domain extends from about 0.33 kHz to 4.36 kHz, the SPL being 62.03 dB.

Rana alticola (Plate 1f. ABC & Fig. 1f; Tables 1, 2 & 3)

1. **Habit and Habitat:** Found in ponds, ditches, beels and low lying areas abundant in aquatic vegetation.

2. **Coloration** (Plate 1f. A): Dorsally yellowish to light brown; two distinct glandular dorsolateral folds running anterior to posterior, ending near the groin. Another glandular fold running from below the eyes and tympanum to the shoulder.

3. **Morphometric measurements and biometric ratios** (Tables 1 & 2): Absolute measurements of 15 morphometric characters and 8 biometric ratios have been compiled for 7 males and 6 females.

4. **Call characteristics** (Plate 1f. BC & Fig. 2f; Table 3): The calls are repeated very rapidly. Each call lasts for about 0.020 s, having approximately 14 pulses, given at a call interval of 0.079 s. The call has a single dominant frequency at about 0.73 kHz, the frequency domain lies between 0.30 kHz to 1.57 kHz, the SPL of the call being 45.47 dB.

Polypedates leucomystax (Plate 1g. ABC & Fig. 1g; Tables 1, 2 & 3)

1. **Habit and Habitat:** This species was mostly collected from Assam. They are found on creepers entwining bamboo fencing or tall grass near the vicinity of water.

2. **Coloration** (Plate 1g.A): Dorsal surface and sides olive to yellowish green; broad pale stripes on dorsolateral folds running between eyelids and groin; ventral surface cream; dorsal surface of legs olive brown with dark markings arranged longitudinally in lines.

3. **Morphometric measurements and biometric ratios** (Tables 1 & 2): Absolute measurements of 15 morphometric characters and 8 biometric ratios have been compiled for 10 males and 10 females.

4. **Call characteristics** (Plate 1g. BC & Fig. 1g; Table 3): Distinct well spaced calls, total call duration being approximately 0.182s with about 13 pulses, given at intervals of about 10.369s. The call has a single dominant frequency at about 2.50 kHz and the frequency domain extends from 1.44 kHz to 3.82 kHz, the SPL of the call being 50.46 dB.

Amolops formosus (Plate 1h. ABC & Fig. 1h; Tables 1, 2 & 3)

1. **Habit and Habitat:** Found by the sides of streams as well as in uninhabited forest caves.

2. **Coloration** (Plate 1h.A): Green with black patches on dorsal surface; ventrally creamish with black patches mostly concentrated on lower jaw and throat.

3. **Morphometric measurements and biometric ratios** (Tables 1 & 2): Absolute measurements of 15 morphometric characters and 8 biometric ratios have been compiled for 10 males and 10 females.

4. **Call characteristics** (Plate 1h.BC & Fig. 1h; Table 3): Can be mistaken for an insect call. The call is a long continuous trill. Sometimes the call consists of two components, a main trill ending with a beep. The call duration is about 1.840 s, having about 21 pulses. With the passage of time the number of pulses increases. The call

is given at intervals of 8.802 s. It is a harmonic call with dominant frequency at about 2.07 kHz and 2.45 kHz. The frequency domain extends from 0.30 kHz to 4.32 kHz, the SPL of the call being 52.7 dB.

Bufo melanostictus (Plate 1i. ABC & Fig. 1i; Tables 1, 2 & 3)

1. **Habit and Habitat:** This species is found throughout the year, mainly on land, under stones and other damp places.

2. **Coloration** (Plate 1i.A): Brown to yellowish brown dorsally with black spots; tips of warts and ridges of head usually deep brown to black; ventrally creamish, at times with light brown spots.

3. **Morphometric measurements and biometric ratios** (Tables 1 & 2): Absolute measurements of 15 morphometric characters and 8 biometric ratios have been compiled for 10 males. Data from females not taken into account, since the number of females collected was less than 5.

4. **Call characteristics** (Plate 1i. BC & Fig. 1i; Table 3): The loud croaks can be heard from a distance. These are rapidly repeated calls, the call duration being approximately 0.103 s with as many as 105 pulses, given at intervals of about 0.134 s. The call has a single dominant frequency at about 1.69 kHz. The frequency domain extends from about 0.34 kHz to 4.01 kHz, the SPL of the call being 59.21 dB.

Hoplobatrachus tigerinus (Plate 1j. ABC & Fig. 1j; Tables 1, 2 & 3)

1. **Habit and Habitat:** Commonly known as tiger frog, and always found near water in weed-choked ponds, ditches, tanks and marshes. During monsoon they are widespread in flooded lowlands. Mostly found singly, on sunny days they often spend hours crouched in grass or at the entrance of drains and culverts. Though strong jumpers and swimmers, they are easy to catch since they keep sitting motionless for hours together.

2. **Coloration** (Plate 1j.A): The dorsal coloration of the adult is light brown to olive,